Spatial and temporal dynamics of photosynthesis regulation of genetically defined coral/algal symbiosis associations

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy by

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Certificate

The work presented in this thesis, and the research to which it pertains, are the product of my own work and, to the best of my knowledge and belief, original. Any ideas or quotations from the work of others, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline. Co-authors of published, submitted articles and articles in preparation were involved in two or more stages of a study including **a**) planning of the study, **b**) essential expertise and support with field and laboratory work, **c**) critical evaluation of the material and literature and **d**) final interpretation and writing up of the results. Material has not been submitted, either in whole or in part, for a degree at this or any other university.

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Publications

Peer-reviewed journal articles arising directly from this thesis

Ulstrup KE, Berkelmans R, Ralph PJ, van Oppen MJH (2006) Variation in bleaching sensitivity of two coral species across a latitudinal gradient on the Great Barrier Reef: the role of zooxanthellae. *Marine Ecology Progress Series* 314:135-148.

Ulstrup KE, Ralph PJ, Larkum AWD, Kühl M (2006) Intra-colonial variability in light acclimation of zooxanthellae in coral tissues of *Pocillopora damicornis*. *Marine Biology* 149:1325-1335.

Peer-reviewed journal articles relevant to the thesis but not forming part of it

Ulstrup KE, Kühl M, Bourne D (2007) Zooxanthellae harvested by ciliates associated with brown band syndrome of corals remain photosynthetically competent *Applied Environmental Microbiology* 73:1968-1975

Ulstrup KE, Hill R, Ralph PJ (2005) Photosynthetic impact of hypoxia on *in hospite* zooxanthellae in the scleractinian coral *Pocillopora damicornis*. *Marine Ecology Progress Series* 286:125-132.

Conference abstracts (* poster)

Ulstrup KE, Ralph PJ, Larkum AWD, Kühl M (2006) Intra-colonial variability in light acclimation of zooxanthellae in coral tissues. European Meeting for International Society for Reef Studies, Bremen.

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Ulstrup KE, Ralph PJ, Larkum AWD, Kühl M (2005) Intra-colonial variability in light acclimation of zooxanthellae in coral tissues. Australian Coral Reef Society 81st Annual Conference, Heron Island, Australia.

Hill R, **Ulstrup KE** (2005) Imaging-PAM: operation and possibilities. Coral Reef Targeted Research and Capacity Building for Management Workshop, Puerto Morelos, Mexico.

Ulstrup KE (2004) Coral Bleaching - Integrating physiology with genetics. Scandinavian Protozoological Meeting, Helsingør, Denmark.

Ulstrup KE, Berkelmans R, Ralph P, van Oppen M (2004) Bleaching sensitivity of two conspecific corals on a latitudinal gradient. International Society for Reef Studies, 10th International Coral Reef Symposium, Okinawa, Japan.

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Abstract

Photosynthetic capacity of scleractinian corals relies predominantly on the productivity of single-celled endosymbiotic dinoflagellates of the genus *Symbiodinium*, known as zooxanthellae, residing intracellularly within coral endoderm tissue. The regulation of photosynthesis of zooxanthellae is in turn dependent on light and temperature. This thesis explores the genetic basis for variation in photosynthesis capacity of zooxanthellae by examining the photo-physiology of genetically characterised *Symbiodinium* communities at a range of spatial and temporal scales. *In situ* and manipulative experiments were conducted to improve our understanding of metabolic responses of zooxanthellae under climate change scenarios.

Fine scale measurements of irradiance and photosynthesis allowed the assessment of photo-physiological changes across individual colonies of *Pocillopora damicornis* and *Acropora valida*. *Pocillopora damicornis* generally contain genetically homogeneous populations of *Symbiodinium*, whilst genetically diverse *Symbiodinium* communities exist within *Acropora valida*. Measurements of light absorption in *P. damicornis* were conducted using a scalar irradiance microprobe and it was found that light absorption was greatest in shade-adapted polyp tissue and smallest in sun-adapted coenosarc tissue. Genetic heterogeneities, found at the scale of individual polyps in *A. valida*, correlated with O_2 concentration at the surface of the colony which was greater in polyps that harboured the two clades (A + C) than in polyps that only harboured clade C. In both corals, measurements using an O_2 microelectrode and a fibre-optic microprobe yielded dissimilar results when used at moderate to high irradiances.

Seasonal changes in photosynthetic capacity suggested that *P. damicornis* is more sensitive to combined effects of relatively higher temperature and irradiance in summer than *A. valida* suggesting that the symbiont community of *A. valida* may not be physiologically compromised possibly due to phylogenetic changes of *Symbiodinium*. Furthermore, thermal tolerances of conspecific corals were examined at narrow and wide spatial scales across the length of the Great Barrier Reef. *Pocillopora damicornis*, which harboured *Symbiodinium* type C1, thus bleached in correlation with latitude, whereas *Turbinaria reniformis* bleached in correlation with the presence and absence of the known thermo-tolerant *Symbiodinium* clade D.

The results, integrating over spatial and temporal scales suggest that the acclimatisation capacity of corals to light and temperature is determined by i) history of

light and temperature exposure and in cases where corals associate with multiple *Symbiodinium* types ii) the distribution of *Symbiodinium*.